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Remediation of contaminated fine-grained soil by freezing and ion exchange effect

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Abstract

It is extremely difficult to remediate contaminated fine-grained soils by the conventional methods. However, the use of freeze-thaw was proposed for this purpose. This method utilizes the ice segregation phenomena in a frost susceptible soil. Soluble contaminants in the pore structure in a soil can be removed easily by the method than by the conventional method. However, it is extremely difficult to remove adsorbed contaminants on soil's surface even by this method. In order to overcome this problem and improve the method, ion-exchange reaction was proposed. The purpose of this study is to demonstrate the combined effect of freeze-thaw and ion-exchange for remediation of fine-grained soil.

A series of freeze-thaw tests were conducted to remove natural potassium ions from Kizuchi clay by changing freezing conditions such as temperature gradient, freezing speed, type of freezing and the number of repetition of freeze-thaw. As for washing agent, pure water, 0.37 and 0.10 mol/L of ammonium acetate solutions were compared. The test specimen was frozen from the bottom side to top direction while washing agent was supplied from the top side. The specimen was thawed almost instantly and the drainage was taken from the bottom side of the specimen to measure potassium level. Furthermore, the distribution of potassium concentration was measured in the freeze-thawed specimen. The potassium concentration was obtained by atomic absorption spectrometry.

Conclusions are as follows; (1) Ammonium acetate solution was effective to remove natural potassium in the freeze-thaw process but pure water was not. (2) Level of potassium concentration in the drainage increased with the repetition of freeze-thaw. (3) Remediation efficiency was increased with greater temperature gradient, slower freezing speed and increased number of repetition.

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1. Introduction

Contaminated soil with heavy metals is caused by leakage of contaminants from chemical factories and waste landfill sites. Particularly in soil contamination, heavy metals dissolved in rainwater and the like permeate into the ground, and they are easily adsorbed by the interaction with the soil particles and remain near the surface layer [1]. As a current remediation method, grounds with high permeability coefficient have been applied in Soil Washing and In-situ Soil Flushing [2]. However, in the ground with low permeability coefficient, washing remains and the cleaning efficiency drastically decreases and an effective remediation method has not been established.

On the other hand, we have been experimentally investigating whether it is possible to apply a washing technique based on the frost heave phenomenon to contaminated soil containing a large amount of fine-grained [3]. The frost heave phenomenon is a phenomenon peculiar to fine-grained soil. When the soil is cooled to 0℃ or lower, the pore water in the soil is frozen and an ice lens is generated. As long as freezing continues, several layers of ice lenses are formed by supplying moisture from the unfrozen part [4]. It is also known that the permeability coefficient of the ground increases remarkably after thawing [5]. In this technique, even on a fine-grained ground with low permeability coefficient, moisture transfer occurs at the time of freezing, and moisture uniformly spreads throughout the ground during the freezing process to perform effective remediation. And contaminated water is drained effectively because the permeability coefficient increased in the freeze-thawed soil [6]. As a result of experiments, ionic substances in pore water were successfully removed though it did not lead to the adsorbed removal of ionic substances on the soil particles [7, 8].

Therefore, in this study, the authors presumed that it is possible to remove adsorbed ionic substances by adding an ion exchange reaction to the remediation technique utilizing the frost heave phenomenon [9]. In the experiment, we attempted to remove potassium ion (K^+) and ammonium ion (NH_4^+) adsorbed on the soil particles by using ammonium acetate solution as a washing solution [10]. In particular this time we are studying (1)effect by washing water, (2)effect of repetition freeze-thaw, (3)effect by the freezing speed and temperature gradient and (4)effect by freezing method.

2. Experimental Procedure

Kizuchi clay (ρ_s = 2.678g/cm^3, *LL* = 53.4%, *PL* = 23.9%, SAND = 0.7%, SILT = 47.3%, CLAY = 52.0%) was used for all the experiments. Potassium contained in the sample was subjected to washing. The soil prepared as a slurry at water content greater than the liquid limit by approximately 1.3 times. After stirred and vacuumed, preloaded was performed at a predetermined pressure. Specimens were shaped to ϕ = 10 cm and h_0 = 5 cm. In addition, the potassium content in the shavings generated the above sample shaping was taken as the initial value.

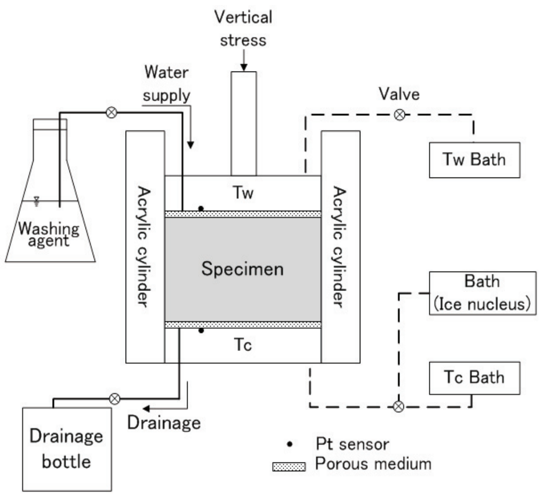

Fig.1 One-dimensional freeze-thaw test system.

The test system used in the experiment is shown in Fig.1. In the experiment, freezing is performed from the lower end of the specimen, and at the same time, washing agent is supplied from the upper end. In the thawing process, the supply of washing agent was ceased and drained from the lower end. The potassium contents in the specimen and in the